INFLUENCE OF SPATIAL AND ENERGISTIC FACTORS ON THE
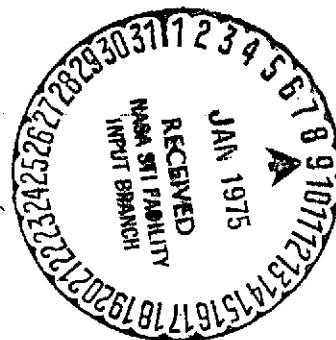# VISUAL FIELD OF AN OPERATOR

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16. Abstract

This article performs a composite study of the influence of the spatial and energistic factors upon the visual field of an operator.

The operator field of vision was studied as a function of the angle of view under the influence of the following factors: the dimensions of the recording, its brightness, color, and external illumination.

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INFLUENCE OF SPATIAL AND ENERGISTIC FACTORS ON
THE VISUAL FIELD OF AN OPERATOR

V. A. Yekimov and V. M. Mironov

One of the characteristics of flying is the diversity and   /124*
complexity of the visual information perceived along with a
large number of changes, both in the properties of the signals
and the conditions under which they are perceived. It is known
that, under certain conditions, the field of vision of an
operator may change greatly, and a reduction in the field of
vision is the most dangerous occurrence.

The signals represented on the screens of the recording
instruments are characterized by different properties — for
example, the dimensions of the reading, its brightness, color,
etc. These characteristics of the signals, as well as the
external illumination of the cabin, are spatial and energistic
factors which influence the work of the operator. The inter-
action of each of these factors upon different characteristics
of the operator optical system has been investigated in several
studies; however, the studies were performed under different
conditions and using different methods. Therefore, it is diffi-
cult to make a quantitative comparison of their results.

This article performs a composite study of the influence
of the spatial and energistic factors upon the visual field of
an operator.

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Methods

The studies were performed on six test subjects between 20 and 28 years old. Before the beginning of the experiment, each of the test subjects had his vision checked, and it was found that the field of vision under standard conditions satisfied the generally accepted norms.

The operator field of vision was studied as a function of the angle of view under the influence of the following factors: the dimensions of the recording, its brightness, color, and external illumination.

For the recording, a projection PPR-60 perimeter was used. Its operation was based on the principle of light projection of the test object upon the perimeter arc. By rotating the arc of the device and changing the position of the object upon the arc, it was possible to place the object in any position on a hemisphere, until the operator could no longer detect it. The coordinates of the points were fixed on a special blank-graph. Recordings were made every 30° of the sighting angle. A curve was drawn on the blank-graph in accordance with the field of vision scheme adopted at the International Ophthalmological Congress in Madrid in 1933, i.e., the field of vision was plotted in the projection in which the experimentor, standing in front of the test subject, sees it.

The curves of the visual field as a function of the sighting angle were formulated as follows:

1) The dimensions and brightness of the object, which remained unchanged throughout the experiment, were determined;

2)   The external illumination, corresponding to daytime, twilight, or nighttime and which also remained unchanged throughout the experiment, was established;

3).   Different colors of the objects were determined, and for each color, curves were compiled for the operator visual field.   The four curves obtained were plotted on one blank-graph.

Similar curves were plotted for all combinations of the object dimensions, values of its brightness, and variations of the external illumination and color of the object.

The spatial and energistic factors which were studied were <u>/125</u> characterized by the following parameters:

1)   dimensions of the objects: 1 mm, 3 mm, 5 mm, and 10 mm;

2)   brightness values of the object: 1.6 millistilb; 0.1 millistilb;   0.012 millistilb;   and 0.0035 millistilb;

3)   variations of the external illumination: daytime — brightness of the perimeter arc, 0.5 millistilb; twilight — arc brightness, 0.02 millistilb; nighttime — arc brightness, 0.00002 millistilb;

4)   color of the object — white, blue, green, red.

Thus, 182 curves of the visual field were obtained for each test subject.   The data for all six test subjects were averaged.
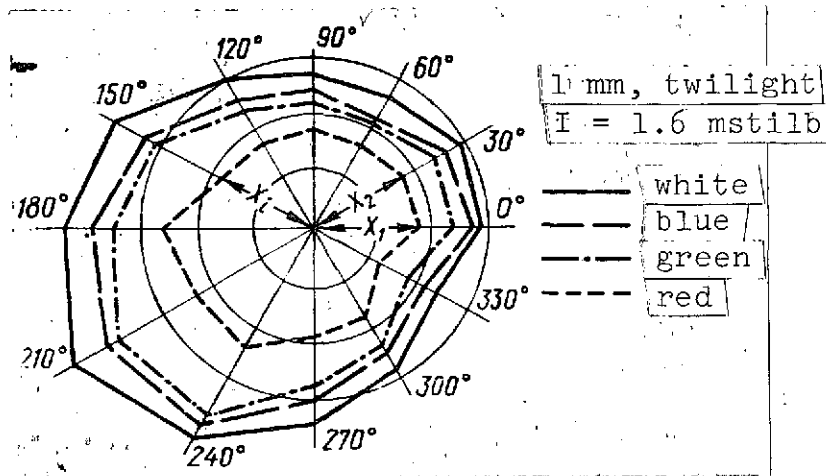
Figure 1. Visual field of operator when sighting objects of different colors with a brightness of I = 1.6 millistilb; dimensions of objects, 1 mm; external illumination — twilight.

Results

By way of an example, Figure 1 shows certain curves for the visual field of an operator (for one eye).

The results of the tests were subjected to statistical processing and for each of the 182 averaged curves, the following parameters were calculated: (

1) the arithmetic mean deviation of the curve of the visual field from its center

$$\bar{x} = \frac{\sum\limits_{i=1}^{n} x_i}{n}$$

where x_i are the values of the distance from the center of the visual field up to a point on the curve corresponding to a given sighting angle (see Figure 1); n — number of recordings of the sighting angles (n = 12); i — number of the recordings;

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2)   mean square deviation of the curve of the visual field from its center;

3)   variational coefficient;

4)   correlation coefficient r of each pair of curves of the visual field drawn for the given dimensions of the object and the external illumination variation:

$$r = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sigma_x \sigma_y (n-1)}$$

where x_i are the values for one of the visual field curves being analyzed; y_i — values for another visual field curve; σ_x and σ_y — corresponding mean square deviations.

The results of the calculations were used to formulate curves for the arithmetic mean and mean square deviations of the visual fields as a function of the color of the object for /127 different brightnesses of the object and variations of external illumination (Figure 2a, b; 3; 4a, b; the colors are arranged in increasing order of wavelengths). The variational coeffi- cients of these curves lie between $V = 0.2 — 0.3$. Certain results of calculating the correlation coefficients are given in Tables 1, 2, 3, and 4.

Each of the tables gives the correlation coefficients of the visual field curves for given dimensions of the object and variations of the external illumination, but corresponding to different colors and brightnesses of the object. The indices of the curves are plotted along the vertical and the horizontal in the tables, i.e., the arbitrary designations of combinations of color and brightness of the object, for which the visual field curves were compiled. Table 5 gives an explanation for the indices.
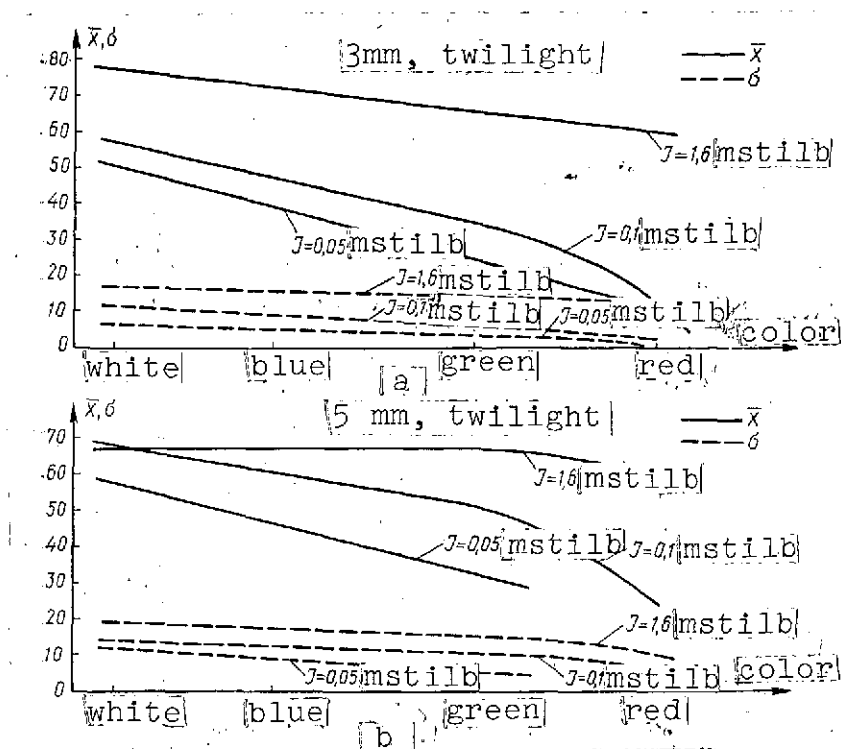
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Figure 2. a) Relations $\bar{x}$ = f (color of the object) and σ = γ (color of the object) for fixed brightnesses I = 1.6 millistilb; 0.1 millistilb; 0.05 millistilb; dimensions of the object — 3 mm; external illumination — twilight.

b) Relations $\bar{x}$ = f (color of the object) and σ = γ (color of the object) for fixed brightnesses I = 1.6 millistilb; 0.1 millistilb; 0.05 millistilb; dimensions of the object — 5 mm; external illumination — twilight.

The ⌐boxes⌐ of the tables (1 — 4) give the values of the correlation coefficients. Thus, for example, the value of 0.785 (Table 1, first row, sixth column) represents the correlation coefficient for visual field curves with indices of 1 and 6, i.e., the ⌐coefficient correlating the curves⌐ for a white object with a brightness of 1.6 millistilb with the curves for a blue object with a brightness of 0.1 millistilb.
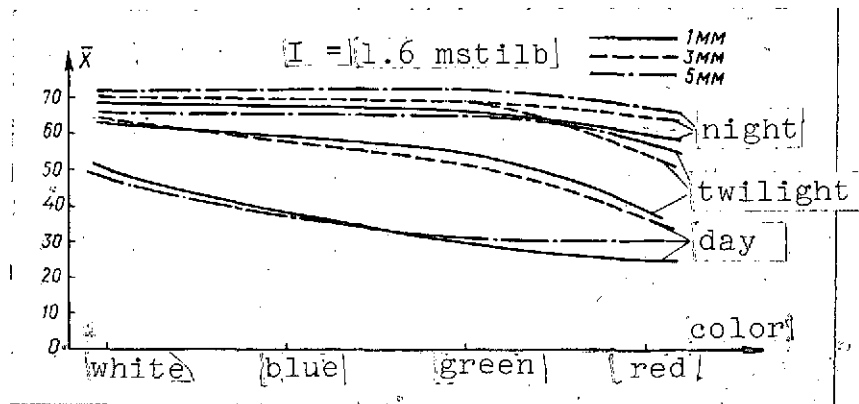
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Figure 3. Relations $\bar{x}$ = f (color of the object) for a brightness of Γ = 1.6 millistilb for objects with dimensions of 1 mm, 3 mm, and 5 mm under different conditions of external illumination.

Discussion

Several characteristic features were discovered during the experiments which must be taken into account when designing the recording instruments.

It follows from the curves shown in Figures 2, 3, and 4 that the arithmetic mean deviation $\bar{x}$ of the visual field curve greatly depends on the brightness of the object and the external illumination. This may be apparently explained by differences in the mechanisms of central and peripheral vision.

It is characteristic that these values are different for /130 the colors of the objects studied. The least reduction in the visual field occurs with a white color for the object. Then follow blue, green, and red in order of increasing reduction of the visual field. This characteristic is more clearly expressed with reduced brightness of the object, with greater external illumination, and with reduced dimensions of the object.

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Figure 4. a) Relations $\bar{x} = f$ (color of the object) and $\sigma = \gamma$ (color of the object) for fixed brightnesses I = 1.6 millistilb, 0.1 millistilb, 0.06 millistilb, 0.012 millistilb; dimensions of the object 3 mm; external illumination — nighttime.
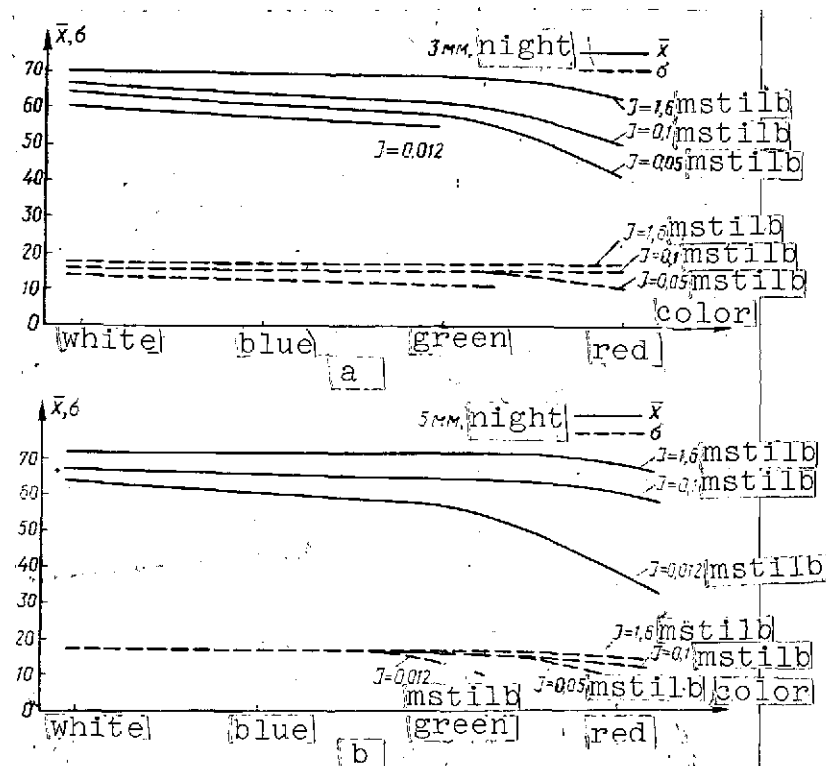
b) Relations $\bar{x} = f$ (color of the object) and $\sigma = \gamma$ (color of the object) for fixed brightnesses I = 1.6 millistilb; 0.1 millistilb; 0.05 millistilb; 0.012 millistilb; dimensions of the object 5 mm; external illumination — nighttime.

An analysis of the correlation coefficients (Tables 1, 2, 3, and 4) shows the mutual influence of these factors on the visual field curves.

TABLE 1

5 mm, twilight

Index no.	1	2	3	4	5	6	7	9	10
1	1	0,995	0,995	0,988	0,930	0,785	0,649	0,838	0,543
2	0,995	1	0,999	0,978	0,929	0,785	0,648	0,845	0,550
3	0,995	0,999	1	0,978	0,935	0,794	0,660	0,853	0,566
4	0,988	0,978	0,978	1	0,942	0,804	0,649	0,846	0,547
5	0,930	0,929	0,935	0,942	1	0,918	0,819	0,908	0,741
6	0,785	0,785	0,794	0,804	0,918	1	0,911	0,884	0,825
7	0,649	0,648	0,660	0,649	0,819	0,911	1	0,820	0,906
9	0,838	0,845	0,853	0,846	0,908	0,908	0,820	1	0,841
10	0,543	0,550	0,566	0,547	0,547	0,825	0,906	0,841	1

TABLE 2

5 mm, twilight

Index no.	1	2	3	4	5	6	7	8	9	10	11
1	1	0,911	0,911	0,917	0,878	0,871	0,843	0,844	0,923	0,945	0,819
2	0,911	1	1	0,989	0,992	0,983	0,981	0,809	0,982	0,949	0,919
3	0,911	1	1	0,989	0,992	0,983	0,981	0,809	0,982	0,949	0,919
4	0,917	0,989	0,989	1	0,982	0,977	0,974	0,831	0,983	0,958	0,911
5	0,878	0,992	0,992	0,982	1	0,983	0,982	0,820	0,980	0,932	0,913
6	0,871	0,983	0,983	0,977	0,983	1	0,984	0,827	0,968	0,931	0,918
7	0,843	0,981	0,981	0,974	0,982	0,984	1	0,760	0,960	0,917	0,894
8	0,844	0,981	0,809	0,831	0,820	0,827	0,760	1	0,826	0,818	0,743
9	0,923	0,982	0,982	0,983	0,980	0,968	0,960	0,826	1	0,966	0,899
10	0,945	0,949	0,949	0,958	0,932	0,931	0,917	0,818	0,966	1	0,912
11	0,919	0,919	0,919	0,911	0,913	0,918	0,894	0,743	0,899	0,912	1

TABLE 3

3 mm, night

Index no.	1	2	3	4	5	6	7	8	9	10	11	12
1	1	0,997	0,998	0,997	0,984	0,986	0,898	0,975	0,969	0,944	0,921	0,940
2	0,997	1	0,997	0,992	0,976	0,980	0,989	0,967	0,960	0,933	0,911	0,930
3	0,998	0,997	1	0,995	0,986	0,987	0,894	0,973	0,970	0,946	0,920	0,944
4	0,997	0,992	0,995	1	0,987	0,989	0,899	0,982	0,976	0,957	0,932	0,952
5	0,984	0,976	0,986	0,987	1	0,908	0,934	0,989	0,989	0,966	0,941	0,970
6	0,986	0,980	0 987	0,989	0,908	1	0,936	0,990	0,991	0,969	0,946	0,969
7	0,898	0,989	0,894	0,899	0,934	0,936	1	0,940	0,949	0,908	0,888	0,916
8	0,894	0,967	0,973	0,982	0,989	0,990	0,940	1	0,986	0,908	0,961	0,978
9	0,969	0,960	0,970	0,976	0,989	0,991	0,949	0,986	1	0,979	0,960	0,984
10	0,944	0,933	0,946	0,957	0,966	0,969	0,908	0,980	0,979	1	0,988	0,965
11	0,921	0,911	0,920	0,932	0,941	0,946	0,888	0,961	0,960	0,988	1	0,946
12	0,940	0,930	0,944	0,952	0,970	0,969	0,946	0,978	0,984	0,965	0,946	1

TABLE 4

5 mm, night

Index no.	1	2	3	4	5	6	7	8	9	10	11
1	1	1	1	0,991	0,940	0,978	0,975	0,970	0,972	0,956	0,947
2	1	1	1	0,991	0,940	0,978	0,975	0,970	0,972	0,956	0,947
3	1	1	1	0,991	0,940	0,978	0,975	0,970	0,972	0,956	0,947
4	1	0,991	0,991	1	0,968	0,986	0,990	0,984	0,975	0,971	0,958
5	0,940	0,940	0,940	0,968	1	0,961	0,973	0,972	0,953	0,969	0,964
6	0,978	0,978	0,978	0,986	0,961	1	0,997	0,991	0,981	0,986	0,979
7	0,975	0,975	0,975	0,990	0,973	0,997	1	0,996	0,979	0,986	0,978
8	0,970	0,970	0,970	0,984	0,972	0,991	0,991	1	0,998	0,982	0,980
9	0,972	0,972	0,972	0,975	0,953	0,953	0,979	0,998	1	0,990	0,989
10	0,956	0,956	0,956	0,971	0,971	0,986	0,986	0,982	0,990	1	0,995
11	0,947	0,947	0,947	0,947	0,964	0,979	0,978	0,980	0,989	0,995	1

TABLE 5

Brightness, mstilb	Color			
	White	Blue	Green	Red
1.6	1	2	3	4
0.1	5	6	7	8
0.05	9	10	11	12